Things of science

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SALT

Unit No. 330

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SALT

This unit of THINGS of science contains seven typical specimens of different types of salt.

Salt which we take so much for granted is one of the most important minerals in our lives. Animals, including humans, cannot exist without it and hundreds of products that we rely upon each day for our needs and comfort require salt in their production.

Exactly when man first noticed salt and recognized its importance is not known, but it was long before the time of recorded history. It has been used to flavor foods, preserve meats and fish as long as we can remember.

Although salt is plentiful and inexpensive today, it was not always so. Wars were fought over the control of sources of salt, even in early America. So valued was salt in ancient days that workers were paid in salt, from which the word "salary" is derived. And many familiar expressions, such as "he is not worth his salt," or "he is the salt of the earth," indicate the influence this mineral has had on our daily lives and culture.

What is the nature of this all-important but commonplace substance and what part does it play in our everyday life?

The materials and experiments in this unit will help you answer these questions.

First identify your specimens.

ROCK SALT—Clear rectangular crystal packaged in the 3 x 5-inch bag with the compressed salt.

COMPRESSED SALT—White pieces of compressed salt used for recharging water softeners.

REGULAR ROCK SALT—Irregular rounded granules; 1/8 to ¼ inch in size; transparent to translucent.

SOLAR SALT—Large irregular angular crystals; ½ to ¾ inch in size in 3 x 3-inch bag.

EVAPORATED SALT—Fine crystals in blue-striped bag; common table salt; granulated.

FLAKE SALT—Small irregular crystals; transparent to opaque white; in plain 3 x 4-inch bag.

TRACE MINERALIZED SALT—Red; mixture of salt and minerals for animal nutrition.

ROCK SALT

Salt is found almost everywhere on earth, in rocks, in the soil, in plants, and, of course, in the ocean. It occurs in almost pure form as great deposits of solid mineral, deep in the earth and on the surface in dried-up beds, and as concen-

trated brine in underground wells.

Most of the salt in the United States comes from mines in the solid deposits underground. Eight states, Louisiana, Texas, Ohio, New York, Michigan, California, West Virginia and Kansas account for more than 90% of the salt produced in the United States.

Experiment 1. Examine your large crystal of rock salt and the smaller granules, samples of regular rock salt. They are more than 300 million years old. These specimens came from mines in Michigan and were contributed by the International Salt Company, Detroit, Michigan.

The samples were once a part of the deposit known as the Salina formation in Michigan which extends into New York State, Pennsylvania, Ohio, West Virginia and Ontario, Canada. The deposit covers almost 70,000 square miles and is several hundred feet thick in some areas.

Millions and millions of years ago when the earth was young and unsettled, its surface was constantly changing. During these tremendous upheavals, oceans sometimes became surrounded by land. Having no outlet they dried up leaving the salt behind as the Great Salt Lake is doing today. Some of these sunken areas filled

with water again only to dry up once more.

Since sea water contains only 3½% salt, you can imagine how much water had to be evaporated and the years it must have taken to create the thick layers of salt.

In some mines layers of salt interrupted by a bed of sediment are visible giving us some insight into the fascinating history of earth formation.

The ocean contains many other chemical substances besides salt, each having its own characteristic solubility. Of these compounds, salt is present in the highest percentage, about 78%.

As the ocean water evaporated, the minerals precipitated out according to their solubility, the least soluble first and the most soluble last forming layers one on top of the other. Salt, which crystallized out when its concentration reached about 26%, formed the thickest deposits.

As the years passed and materials accumulated on top of the salt beds, their weight caused the crystals of salt to become compacted into a solid hard layer of rock salt, the mineral known as halite to mineralogists. Halite is so solid it must be blasted with dynamite for mining, just as in mining coal.

Experiment 2. To demonstrate the compactness and weight of rock salt, make a simple balance with string and 12-inch ruler. Using two containers of the same weight, such as plastic sandwich bags, suspend the rock salt from one end and the empty bag from the other, at equal distances from the center of the balance. Place table salt a little bit at a time into the empty bag until the balance is in equilibrium (Fig. 1).

Now with a small piece of aluminum foil, mold a container the exact volume of the rock salt, keeping the smoothest edge of the crystal at the top. Wrap the foil around the salt, except for the top, pushing it against the crystal to mold it exactly. Cut the aluminum foil to the exact height

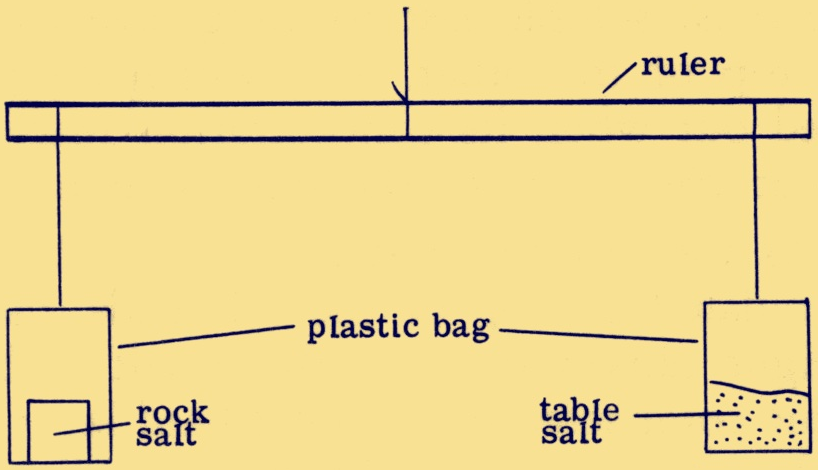

Fig. 1

of the crystal. Remove the crystal and pour the measured table salt into the

mold. Notice how much salt is left after the mold has been filled.

Rock salt contains some impurities, such as calcium sulfare. Bubbles of gas or liquid known as inclusions are sometimes enclosed within the crystals.

Experiment 3. Hold your large crystal of rock salt up to the light. Do you see any bubbles in it? Liquid inclusions, usually brine, are frequently found in halite crystals. Cavities containing liquid inclusions may be only partially filled and the bubbles may move around as you turn the crystal. Does your specimen contain such a bubble?

Inclusions of gas are usually nitrogen, oxygen or a volatile organic substance.

Experiment 4. Sometimes the cavities are cubic with natural crystal planes. Do you see any in your specimen? These cubic cavities follow the crystal formation and are called negative crystals.

Experiment 5. Dissolve several pieces of your granular rock salt in a teaspoon or so of tap water in a small glass or test tube. Do you see any sediment at the bottom of the glass? Anhydrite (calcium sulfate) is present in all rock salt and is the main impurity. It may be present as white or colorless grains that look like sand. Dark impurities are shale.

Your specimen of rock salt came from a flat-bedded deposit. However, in certain areas, such as the Gulf Coastal States in this country, salt deposits occur in what are known as salt domes. About 300 exist along this area.

Salt domes are made up of almost vertical columns of salt, hundreds of feet high beneath the earth. These formations originated from vast salt beds which were gradually pushed upward by pressures from the surrounding area, creeping up through the formation above like huge fingers of solid salt.

Some of these domes have caused mound-shaped protuberances to rise above the surface of the earth. The salt domes are generally covered with a solid layer of rock from 100 to 500 feet deep made up of gypsum, anhydrite and limestone.

Sometimes elemental sulfur is found in the strata containing sulfate minerals, which explains why sulfur mines are found near salt mines in some localities.

To mine rock salt from either flat-bed or salt dome, the usual method is by room-and-pillar mining. A shaft is lowered into the salt deposit and the salt is mined by blasting and cutting away the halite in checkerboard fashion, alternating pillars that support the roof of the mine

with open space for mining. After mining at one level, a new working level is started by cutting vertically downward. The repeated vertical mining results in rooms that may reach heights of 80 to 100 feet and 100 feet in width.

In flat deposits the layer is not as thick as in the salt dome and the ceilings may be only from 8 to 24 feet high.

Most of the sorting, crushing and grading of salt is now done underground. The salt mines today are a far cry from those of yesterday. Modern equipment has automated many of the processes. Even infrared light is now employed for separating impurities from rock salt.

Solution mining is a method often applied in salt domes. In solution mining, the salt is dissolved with water and the concentrated brine is pumped to the surface. A pipe surrounded by an outer casing is lowered to the desired depth and fresh water is injected into the space between the casing and the pipe. The brine thus formed is then pumped up through the inner pipe.

Hydraulic mining is another method for mining salt as an artificial brine. In this method two separate pipes are inserted at different levels a short distance from each other. Water is pumped down

one pipe and the dissolved salt is drawn up the second pipe.

To obtain natural brine a single pipe is usually lowered into the well and the solution pumped to the surface.

NATURE OF SALT

Chemically salt consists of two elements, sodium (Na) and chlorine (Cl), both highly active and harmful to humans in their elemental form. Neither element occurs free in nature, but is found in abundance as the harmless compound, sodium chloride (NaCl) or salt.

Sodium chloride consists of a positively charged sodium ion and a negatively charged chlorine ion. In solid form the ions arrange themselves in a cube-shaped crystal lattice. In solution, separated by the water molecules, the ions move freely and independently.

Experiment 6. Look carefully at the grains of evaporated salt in your unit with a magnifying glass. Note their cubic structure.

Are the crystals transparent? Halite when pure is colorless.

Halite is an isometric crystal, a crystal that has equal sides and equal angles. Each tiny cube of salt represents the crystal formation of the smallest unit of

sodium chloride that exists as a crystal lattice (Fig. 2).

Experiment 7. Note the straight sides of your large rock salt crystal. Examine it carefully. Do you see any lines, like cracks, running across the crystal parallel

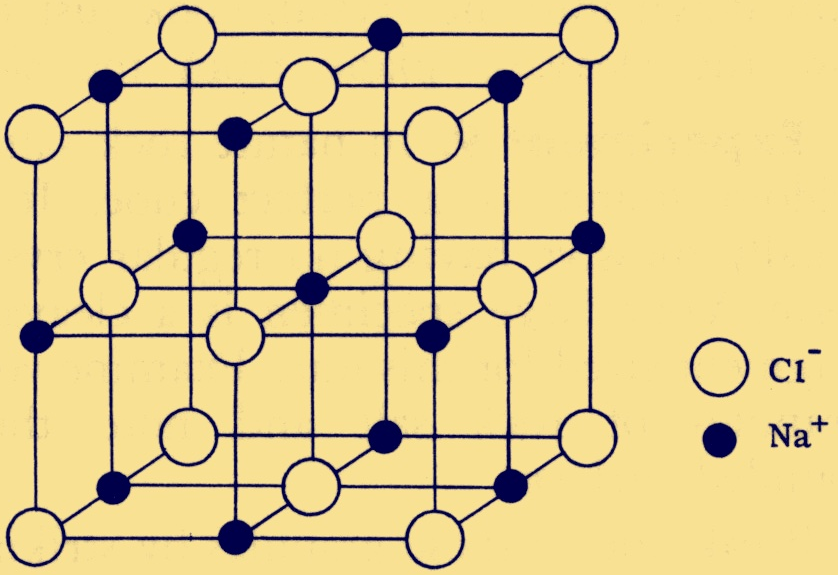

Fig. 2

to the sides? These are cleavage lines along which the crystal will easily split and are determined by the crystal lattice arrangement of the unit cell. Strike the crystal sharply, using a metal instrument such as a screw driver or chisel, directly on the cleavage line. It will make a clean split and the cleavage planes will be smooth and straight.

If you do not see a cleavage line, a sharp impact will cause a line to appear.

Experiment 8. If you strike the cleavage face sharply but not too hard

with a rounded metal surface such as the end of a tool handle or the flat head of a nail, you will produce two tiny fracture lines about ⅛ to ¼ inch long diagonal to the sides. The two cross to form a tiny star. The fractures also extend vertically down into the crystal. Look just below the cleavage plane from the side.

Experiment 9. In nature rock salt is seldom found as a perfect cube. It is usually massive having no regular crystal form. Your large specimen is a cleavage fragment sized for this unit. Examine your granules of rock salt and note their rounded surface.

Break one of these granules by striking it sharply. Does it have perfect cleavage? Break it progressively along cleavage lines and note that you finally produce tiny cubic crystals.

SOLAR SALT

Evaporation of enclosed shallow pools of sea water using the heat of the sun was probably man's first substantial source of salt.

Salt is still produced in many areas by solar evaporation. However, since this method depends upon a favorable weather pattern, most of the solar salt in the United States is now produced in Califor-

nia, especially in the San Francisco Bay Area. Solar salt plants also exist in Utah and Nevada.

Your sample of solar salt was provided by the Western Salt Company, San Diego, California.

Experiment 10. Note the irregular layered structure of the solar salt. Solar salt is called hopper salt because of its shape which results from the way in which the crystals grow during solar evaporation.

As water evaporates from the pool of concentrated brine, nuclei of salt crystals form near the surface where the solution is most saturated. These tiny crystals remain afloat, held there by surface tension.

The crystal, as it grows in its usual cubic formation, becomes heavier and sinks a little. The crystal continues to grow extending laterally, or to the sides. With increased weight it sinks a little deeper. Lateral growth begins again. This step-like formation continues until the crystal becomes so large it drops to the bottom of the pool. The result is a hollow hopper shape like a four-sided inverted pyramid. (Fig. 3).

Your specimen is not a complete hopper since the crystal has been broken

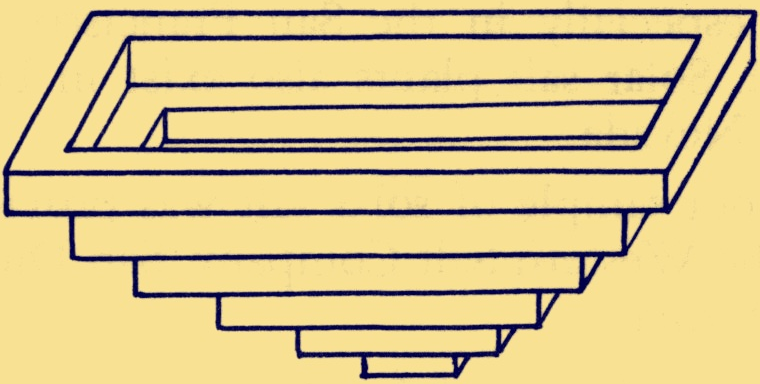

Fig. 3

down to this size. However, you can see the step-like layers.

Experiment 11. Break the crystal by striking it sharply. Look at the cleavage face carefully and you will see a fine line where the crystals join to form the corner of the pyramid.

The manufacture of solar salt is generally by the pond method. A series of large shallow ponds separated by levees are built close to the source of the water.

Sea water from the ocean is collected in the largest ponds. Here the suspended particles of sand, etc., are permitted to settle out of the brine. The brine is then transferred as its concentration increases to other ponds where calcium sulfate is deposited. When the brine reaches saturation, it is transferred to the final harvesting pond where sodium chloride crystallizes out. The brine at this stage still contains the so-called bittern salts, mag-

nesium chloride, potassium chloride, magnesium sulfate, some bromine salts and traces of other elements in solution. It is therefore drained off before all the sodium chloride is precipitated to prevent deposition of the bittern salts which would contaminate the product.

As the crystals accumulate at the bottom they become joined into larger irregular crystal masses.

Experiment 12. Simulate solar evaporation of salt using a concentrated solution of table salt consisting of a quarter cup of the salt dissolved in a cup of cold water. Place the brine in a shallow pan so that the solution is about a half-inch deep. If the weather is good, place outdoors where the sun will strike it most of the day. The brine should remain completely undisturbed.

Watch the crystal growth from day to day. Notice how the first tiny crystal nucleus appears at the surface and remains suspended there.

Examine the crystals accumulated at the bottom with a magnifying glass. Are any crystals hopper shaped?

Experiment 13. Note that some crystals form within the solution. What shape are these?

EVAPORATED SALT

One of the most important forms of salt is the familiar table salt.

Experiment 14. Take a few grains of the evaporated salt in your unit and examine them under a magnifying glass. Note that they are clear cubic crystals and closely uniform in size. Evaporated salt is also known as granulated salt.

Your specimen was contributed by the Morton Salt Company, Chicago, Illinois.

The production of salt by evaporating brine with artificial heat has been practiced for thousands of years. In the early days, the apparatus consisted of flat iron pans which were filled with brine and then heated over an open fire. Today a much improved system, the vacuum pan method, is used.

Steam heat is applied to heat the brine under low pressure in vacuum pans which are huge vessels about three stories high. As the brine boils and evaporates, crystals of salt form within the brine and drop to the bottom of the vessel. To produce the fine cubic crystals, the brine is boiled vigorously and continuously kept in motion by means of an agitator. Crystals can grow into perfect cubes only if they are free to grow in every direction.

The crystals mixed with brine are

pumped away, passed through a filter, removed and dried.

The size and shape of the grains in table salt are important to the consumer. If the granules are too small, the salt will cake easily; if they are too large, they will not dissolve quickly enough. If the shape is irregular instead of uniformly cubic, the salt will not flow freely from the salt shaker.

Experiment 15. Salt is deliquescent, that is, it has a tendency to absorb moisture readily from the air. To help counteract this property, calcium silicate, magnesium silicate, or aluminum calcium silicate is added. These chemicals have a great capacity for adsorbing water and by removing moisture from the air, prevent its sorption by the salt. However, if the atmosphere is extremely humid, the salt will absorb some moisture which might prevent it from being free flowing if this additive alone were present. A very small amount of yellow prussiate of soda is therefore added to prevent any possibility of caking. The salt also contains a small amount of potassium iodide to prevent goiter.

Experiment 16. Take a small sample of your evaporated salt and place in a small open jar. Place the jar in a covered

saucepan containing a quarter of an inch or so of water and let stand overnight.

Crush a few of your granules of rock salt into fine crystals and also place in an open jar in the covered pan.

Which specimen of salt absorbs the most moisture?

Experiment 17. Remove both salt specimens from the pan. Allow to dry out. Do both samples cake? When untreated salt is allowed to become damp and dry out again repeatedly, it will cake and become a hard mass.

As the water evaporates from the damp salt, microscopic crystals of salt grow in the dissolved salt. These tiny crystals eventually form a solid bridge between the larger crystals if repeatedly dissolved and crystallized and cement them together. The yellow prussiate of soda causes the salt crystals which form these bridges to be feathery or dendritic crystals which break apart easily.

Experiment 18. Repeat the above experiment using granules of rock salt. What are your results?

Smaller particles have a greater tendency to cake than larger crystals. Rock salt does not ordinarily cake because of its size and shape.

FLAKE SALT

Your specimen of flake salt, donated by the Diamond Crystal Salt Company, St. Clair, Michigan, is prepared by a special method known as the Alberger process, a modification of the grainer process, generally used to produce flake salt.

The Alberger flake salt is grown in large open pans by crystallization at the surface of the brine and like solar salt, the product is hopper shaped.

The brine is first heated gradually to a temperature of 290°F. under pressure so that it does not boil. Then the pressure is released in a series of units known as flashers permitting the brine to cool to 226°F. The salt begins to crystallize from the brine as it leaves the last flasher and enters the open evaporator pan.

Delicate flake-like crystals form on the surface and continue to grow at the surface until they sink to the bottom. The crystals are raked automatically into a large well and then carried by conveyors to another part of the plant where they are dried, screened and classified.

Experiment 19. Examine the flake salt crystals under a magnifying glass. How does this salt differ from the granulated salt?

Flake salts are used chiefly for surface

salting of crackers, saltines, pretzels and similar foods.

Experiment 20. If you have saltines or pretzels handy, examine the salt sprinkled on their surfaces. Is it flake salt?

In the grainer process, the dissolved purified salt is heated in large shallow open pans by steam at a temperature just below the boiling point.

As the water evaporates, tiny crystals of salt float on the surface of the brine. Grainer salt like flake and solar salt is also hopper shaped.

Experiment 21. In a shallow uncovered pan place a cup of concentrated salt solution and heat slowly over boiling water. Observe the crystals as they form. Carefully lift out a few and examine them closely. Can you see the striations that show the step-like growth of the crystals?

Grainer salt, unlike solar salt, is produced by rapid evaporation, but if the temperature of the brine becomes too high, evaporation is too fast and too many fine flakes are formed.

Experiment 22. Devise an experiment to demonstrate this.

Experiment 23. Compare the crystals you obtained by solar evaporation with those formed by evaporation with artificial heat.

Experiment 24. Flake salt finds use as a surface salt because it does not bounce or roll as does granulated salt.

Sprinkle some flake salt and some granulated salt on a smooth inclined surface. Which salt adheres to the surface and stays where it is poured?

TRACE MINERALIZED SALT

Sodium chloride is a constituent of all body fluids and the amount of salt in our system is normally maintained at a constant level by our kidneys. If the balance is in any way disturbed, symptoms soon appear to warn us of the danger. In some types of illness excess salt is retained in the body and swelling or edema occurs. Frequently salt is depleted from the body due to overexercise, heat or both and general weakness, muscle cramps and dehydration may result. Some people need to increase their salt intake during the hot summer months. Animals show similar symptoms when their salt balance is upset. Most of us take in enough salt through our daily diets.

However, strictly vegetarian animals, such as cows, sheep and horses, require a supplement of salt each day to fulfill their body requirements since their foods, mostly cereal, are low in salt content.

Animals since prehistoric times have

sought salt licks to supply this need.

Farm animals, however, have no need to go searching for salt licks. Salt is provided for them each day, scientifically prepared in the form of mineralized salt, like the sample in your unit, or as salt blocks. These salt supplements not only contain sodium chloride, but other minerals essential to the animals.

Experiment 25. Examine your sample of red trace mineralized salt which was supplied by the Diamond Salt Company.

Place a half teaspoon of the mineralized salt in a small amount of water. Can you see the crystals of salt? Are the crystals cubic? Pure granulated salt is usually used for this purpose.

In your specimen the minerals are provided in the form of manganese oxide, iron carbonate, copper oxide, calcium stearate, cobalt oxide, calcium iodate and zinc oxide. Iron oxide is also added but only to give the supplement its red color.

Animals will take in only as much salt as their body demands. Therefore, salt is a self-limiting dietary material. This animal characteristic is utilized to regulate the intake of protein supplements. A specified amount of the mineralized salt is added to the protein food. The animal will stop

eating the supplement when it has had its quota of salt for the day and at the same time eat just enough protein, thus avoiding waste.

COMPRESSED SALT

In the many areas where water hardness is a problem, water softening equipment is widely used in industrial plants as well as in the home.

To reduce hardness without affecting the taste and drinking quality of water, a system based on ion exchange may be used. In the ion-exchange method, the ions of minerals causing hardness are exchanged for harmless ions.

The method itself is very simple. The water softener is partially filled with tiny plastic beads saturated with sodium ions, and as the hard water passes over them the calcium and magnesium ions, responsible for the hardness, are attracted to the beads and replace the sodium ions which then go into solution. No change occurs in the plastic beads.

The water containing the sodium ions is now soft and ready for use.

After a certain period of usage, the beads become saturated with the hardness ions and lose their effectiveness and the system must be regenerated.

To recharge, the procedure is reversed and this is where the compressed salt

comes into play.

Experiment 26. The white pieces of compressed salt in this unit are especially designed for recharging water softeners and were provided by the Morton Salt Company.

When recharging, the water softener is first washed with tap water. Salt is then introduced into the apparatus and water added to dissolve them. The resulting brine washes down through the resin and as it does so its sodium ions replace the hardness ions which then go into solution and are drained away along with the chloride ions remaining in the brine. The softener now regenerated is ready for operation again.

Experiment 27. Compressed salt is made from evaporated salt. Dissolve a piece of compressed salt. Note how clear the water remains.

LOW TEMPERATURE APPLICATIONS

Experiment 28. As you know salt is added to the crushed ice in an ice cream freezer to lower the temperature in order to freeze the liquid ice cream mixture.

The principle involved is that the ice in forming a solution due to the presence of salt, releases the latent heat of fusion. As a result the temperature of the ingredients in the ice cream freezer is reduced to

far below the freezing point of water.

To demonstrate this, make a 50-50 mixture of salt and crushed ice. Lower a small container, such as a plastic sandwich bag, filled with water into the mixture. Does the water freeze? Take the temperature of the brine. How many degrees below the freezing point of water is the solution?

Repeat, using just plain ice. Compare your results.

Rock salt is sprinkled on streets for snow and ice removal, also because of its ability to quickly reduce the freezing point of water.

When salt is scattered on ice, it is so soluble it immediately begins to dissolve in the moisture present on the surface of the ice, causing the ice to melt. The resulting liquid dissolves more salt which in turn melts more ice and so on. It is not necessary to use an amount of salt that will exactly melt all the ice or snow on the street in order to make the road passable.

Experiment 29. Place about 1/16 to ⅛ inch of water in a shallow pan and freeze it. When it is solidly frozen note how tightly the ice clings to the pan.

Now sprinkle some of your granular rock salt on the surface of the ice. Notice how the salt immediately begins to melt

the ice and travels straight down through it. (Drop a piece of rock salt in a glass of water to explain why the salt goes straight down through the ice.) Allow the brine to work its way between the ice and the bottom of the pan. Note how easily the ice can now be removed.

The same action takes place when the rock salt is sprinkled on an icy road. Therefore, more important than simply melting the ice is the salt's ability to puncture the ice by working its way straight down through it and breaking the tight bond between the ice or snow and the road surface.

The two effects combine to allow the snow plow to easily break the ice and scrape it off the road.

Experiment 30. The size of the salt granules is also important in ice removal. Put about an inch of water in a wide-mouthed transparent jar and allow the water to freeze.

Then place 2 or 3 granules of your regular rock salt on its surface, a few grains of evaporated salt and a larger piece of rock salt broken from your crystal. Compare their rates and depth of penetration. Which size would you use for ice removal purposes? Why?

Salt of medium size, grade CC, ⅛ to

¼-inch in size is usually used for this purpose.

Experiment 31. Place a saturated solution of salt with an excess of salt in a tray in the freezer and allow to remain undisturbed for several days. Then remove carefully and note the flat transparent crystals that look like ice formed along the outer edges of the excess salt. The clear crystals are salt dihydrate ($NaCl \cdot 2H_2O$).

Carefully remove some of these crystals and place on a piece of tinted facial tissue or absorbent cloth and allow to dry. Note the white powdery crystals that remain. The salt dihydrate quickly melts when placed in a warm temperature leaving pure sodium chloride behind.

As the salt dihydrate forms, salt is removed from the solution and the brine decreases in concentration so some of the excess salt goes into solution maintaining the low temperature of the brine.

Utilizing this property of brine, salt has been obtained in the polar region by freezing sea water since prehistoric times.

In freezing temperatures, the ice is removed from the surface of entrapped sea water repeatedly as it forms, thus con-

centrating the brine. When the brine becomes saturated, ice no longer forms but salt dihydrate crystallizes out. The sodium dihydrate is then collected and dried to obtain pure salt.

Experiment 32. How can brine be utilized to prevent icing of car windows?

Wipe the outside of a glass with a cloth that has been dipped in a concentrated salt solution. Wipe another with plain water.

Place both glasses in the freezer. Remove after an hour or so. Which glass remains clear and which is clouded?

Appreciation for cooperation in producing this unit is expressed to the Salt Institute, Alexandria, Virginia, whose members in addition to those mentioned in the text include American Salt Corp., Canadian Salt Co., Ltd., Carey Salt Co., Cargill, Inc., Sifto Salt Div. of Domtar Chemicals Ltd., Gordy Salt Co., Hardy Salt Co., Leslie Salt Co., Michigan Salt Co., Oliver Bros. Salt Co., Solar Salt Co., United Salt Co., Watkins Salt Co., Compagnie des Salins du Midi, Imperial Chemical Industries Ltd., Salzdetfurth Aktiengesellschaft, N.V. Koninklijke Nederlandsche Zoutindustrie and Solvay & Cie.

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